KNOWLEDGE SUPPORT SYSTEMS FOR CONSTRUCTIVELY CHANNELING CONFLICT IN GROUP DYNAMICS

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Abstract: The theoretical foundations for individual and collective dynamics are developed in terms of relations between knowledge structures. Neither individuals nor collectives need to be consistent in their knowledge structures to achieve effective performance, and the notion of conflict arises in modeling failures in coordination attributed to such inconsistency. Methodologies for eliciting and modeling knowledge structures from individuals and groups are described, and examples are given of the methodologies applied through computer-based systems to make overt the nature and sources of conflict.

INTRODUCTION

The focus of the research reported in this paper is the effective channeling of conflict in cooperative groups to achieve group objectives. Our theoretical position is constructivist in viewing conflict, both intra-individual and inter-individuals, as natural and essential to adaptive, anticipatory systems. Social processes enable the human species to form compound entities with a greater repertoire of adaptive behaviors than their components, and this involves managing diversity, recognizing the weaknesses of conformity, and encouraging and welcoming conflict that is essential to group creativity and goal achievement. The essence of group dynamics is that the compound entity forms a construct system that subsumes those of the different roles played by the individuals participating in the group. Group achievement involves the dual polarities of a core consensus that binds the group together, and encircling conflicts that give the group richer scope for creativity than is feasible for its parts. From a constructivist perspective what is most remarkable about human social behavior is the possibility of communication and consensus given the essentially idiosyncratic nature of personal models of the world.

These issues and this viewpoint are well-established in group dynamics (Patton and Giffin, 1988), and operationalized through the activities of group facilitators operating to develop and channel constructive conflict. Our research has focused at one level on the practical impact of information technology in facilitating group processes, and at another level on the operational development of the constructivist theoretical position through logical and computational models grounded in cognitive science and artificial intelligence. The research is long-term and, over the past twenty years, has gone through a complete cycle. In the mid-1970s we developed highly interactive computer systems, on the one hand to facilitate group cooperation in goal-directed activities in domains such as stock exchange trading and hospital management (Gaines and Facey, 1975), and on the other hand to facilitate the mutual understanding of conflict in industry relations through the overt modeling of consensus and conflict in conceptual models (Shaw, 1978, 1979).

In the 1980s the systems and techniques developed became valued as a basis for knowledge acquisition in the development of knowledge-based systems, and this led to the development of new methodologies and associated tools that reflected the need for knowledge to be not only overt but also operational (Shaw and Gaines, 1983, 1987). In the 1990s, with the growth of interest in computer-supported cooperative work, we have begun to revisit the objectives and systems of the seventies and apply the new technologies arising out of knowledge-based systems to the support of goal-directed communities, such as international collaborative research programs (Shaw and Gaines, 1993; Gaines and Shaw, 1994).

Much of our previous work on eliciting and modeling consensus, correspondence and conflict in terminological and conceptual systems has been reported in the literature (Gaines and Shaw, 1989; Shaw and Gaines, 1989). It has resulted in individual and groupware interactive programs that are used to facilitate group processes (Shaw and Gaines, 1991a,b). This paper also reports on recent work that extends the previous systems by using concept mapping techniques to develop multi-level models of relations between concepts in group situations. The mapping work has been reported in terms of experiments to support individual creativity (Gaines and Shaw, 1993b), as a tool for knowledge acquisition (Woodward and Shaw, 1994), and as a basis for modeling and supporting the knowledge processes of scientific communities (Gaines and Shaw, 1994).

The first section is an overview of the theoretical underpinnings in terms of a constructivist model of group dynamics. The second reviews work on eliciting terminological and conceptual consensus, conflict and correspondence using repertory grids on a network. The third section introduces concept maps, describes KMap a groupware tool for concept map development, Case Map an interviewing front-end to KMap that using laddering techniques to elicit concept maps of goals, their rationales and example applications.

A COLLECTIVE STANCE

The theoretical position underlying the methodologies and tools described is a *collective stance* that models humanity as a single organism distributed in time and space by recursive partitioning into parts similar to the whole (Gaines, 1994). The phrase is chosen by analogy with Dennett's (1987) intentional stance, because its primary justification is one of utility. A collective stance provides a convenient perspective from which to view phenomena of human existence, including behavioral and knowledge processes, and the role of technological support systems.

The parts into which the human organism is recursively partitioned include societies, organizations, groups, individuals, roles, and neurological functions. Many concepts that apply to individuals may be applied to social systems, not as metaphors or analogies, but because, from a systemic perspective, they are the same concepts being applied to different partitions of the system. Notions of expertise arise because the organism adapts as a whole through adaptation of its interacting parts. The behavioral mechanism is one of exchange of reinforcement through some parts allocating tasks to others. The preferential allocation of tasks to those parts which have performed well previously also gives those parts access to experience enabling them to adapt and perform better in the future. This positive feedback leads to functional differentiation of the parts and the distribution of activities.

From a functionalist perspective, the coordination of the activities among the parts leads to phenomena of communication, discourse and language. The short lives of individual parts would lead to loss of knowledge by the organism as a whole unless compensated by social interactions supporting knowledge transfer, including the generation and storage of overtly represented knowledge. The improved performance resulting from adaptation may be modeled as the part involved having acquired a model of its task. Reflective processes in which parts model the behavior of other parts including themselves leads to a hierarchy of models of increasing abstraction, and detachment from direct experience.

The modeling of human activity in terms of behavioral contingencies and its modeling in terms of symbolic interactions are complementary analyses of the same phenomena. There will be some situations which are more richly represented by one of the analyses and poorly by the other. Many of the phenomena of human action and expertise are behavioral and do not involve significant symbolic representations.

Neither individuals nor collectives need to be logically consistent or coherent in their knowledge structures to achieve effective performance. The notion of conflict arises in modeling individuals and collectives as a construct of the observer to account for inconsistency and incoherence. Conflict is significant because many diverse adaptive and goal-seeking activities may be modeled in general terms as conflict-resolution behavior.

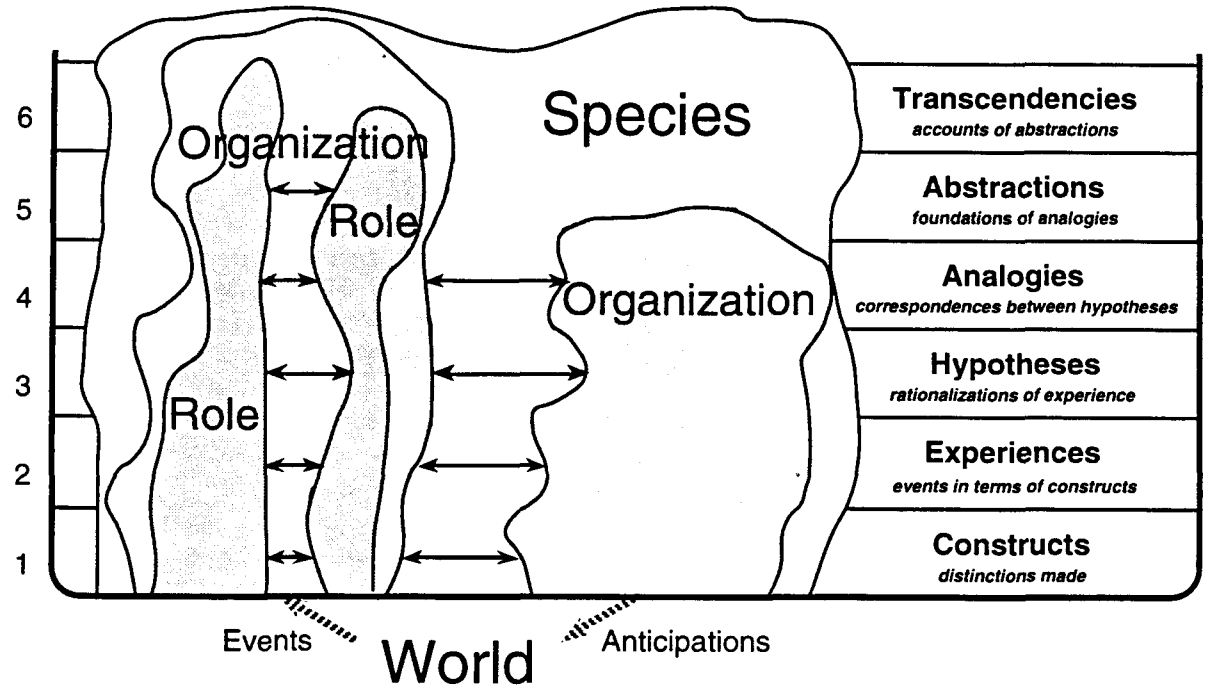

Figure 1 Collective epistemic model of individual and social structures

Figure 1 left shows the relationships between roles within individuals, social organizations and the species in terms of the collective stance model. Figure 1 right shows the knowledge structures of these entities classified in terms of Klir's (1985) *epistemological hierarchy*. Klir has developed a general theory of entities that model their world in terms of a hierarchy of systems: a *source system* providing a descriptive terms, a *data system* providing descriptions in these terms, a *generative system* providing a regeneration of these descriptions in terms of a *structure system* providing theoretical terms, itself described through *meta-systems*, *meta-meta-systems*, etc. The terminology of the right of Figure 1 rephrases this in psychological terms. *Constructs* are the distinctions made to provide descriptive terms. These are used to provide data through the description of *experience*. *Hypotheses* are developed to rationalize experience and tested in terms of the extent to which they can re-generate it. Comparisons between hypotheses are used to develop *analogies* between different modeling structures. These analogies are *abstracted* to provide meta-models of the forms of models, and further abstracted to suggest *transcendent principles* that are meta-meta models of the basis of modeling itself.

Language arises in the collective stance model as a coordination mechanism supporting discourse between the parts of an organism in order to coordinate its overall activities. *Actions* arise as constructs which are applied actively to the world in order to make it construable in some desired form. *Conflicts* are modeled abstractly as any failure of coordination, and hence conflicts may be instantiated through a diversity of phenomena such as inconsistent actions, inconsistent models at different levels, inconsistent terminology in discourse, and so on. Note, however, that inconsistency alone does not necessarily lead to conflicts—effective coordination can occur despite major inconsistencies. It is failure of coordination ascribed to inconsistency that may be properly termed conflict—failure ascribed to the vagaries of the world or inadequate models of it is not indicative of conflict. This definition also relativizes the notion of conflict to the perception of failure. One observer may construe a group's activities as successfully coordinated even though another may see them from a different perspective as failing through conflict. This is what leads to notions of the positive influence of conflict.

The following sections describe computer-based elicitation and modeling methodologies for developing models of the knowledge structures of individuals and groups.

ELICITING CONCEPTS AND TERMINOLOGY

The major methodology that we have used for the elicitation of concepts and terminology from individuals and groups is based on extensions of the repertory grid technique originally proposed by Kelly (1955) as an empirical measurement methodology appropriate to personal construct psychology. Repertory grid techniques elicit knowledge indirectly by prompting individuals for critical elements and relevant constructs in a coherent sub-domain. The techniques are difficult to undertake manually as they require feedback and management from the elicitor while at the same time attempting to avoid inter-personal interactions that would distort the elicitee's conceptual structures. Hence the advent of the personal computer in the mid-1970s and its evolution into the graphic workstations of the 1980s has made the computer implementation of interactive repertory grid elicitation an attractive area of development (Shaw, 1980, 1981; Mancuso and Shaw, 1988). This became particularly so in the later 1980s when the need for tools for interviewing experts in the development of knowledge-based systems became apparent (Gaines and Shaw, 1980; Shaw and Gaines, 1983, 1987; Boose, 1984; Boose and Bradshaw, 1987; Boose and Gaines, 1988).

The repertory grid methodology gives a basis for approximating intensional distinctions through their extensions when applied to elements in a domain. The distinctions made by two individuals can then be compared in terms of the differences in their extensions and in the terminology used. The two relations of similarity between distinctions and between terminology give rise to a four way classification of concepts (Gaines and Shaw, 1989; Shaw and Gaines, 1989). *Consensus* arises if the conceptual systems assign the same term to the same distinction. *Conflict* arises if the conceptual systems assign the same term to different distinctions. *Correspondence* arises if the conceptual systems assign different terms to the same distinction. *Contrast* arises if the conceptual systems assign different terms to different distinctions.

Figure 2 provides a framework for the detailed analysis, elicitation and modeling of knowledge structures and the relations between them. Two roles within the same or different individuals are characterized by the knowledge structures used for perception and action within a domain, and as the basis for discourse. Coordination between the roles to form a collective can occur through joint action within the domain, through discourse, or through some combination of the two.

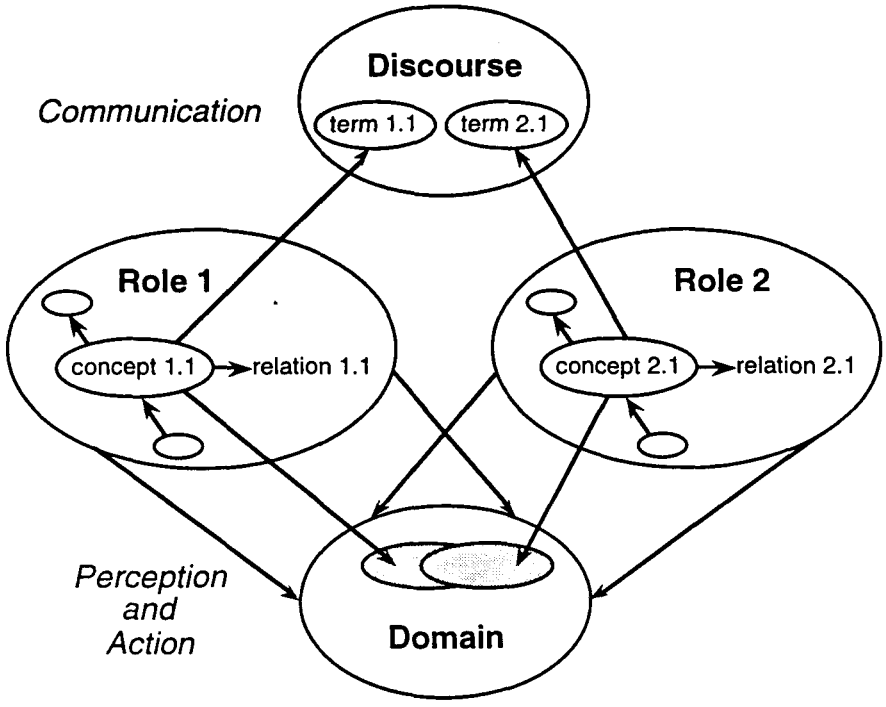

Figure 2 Relations between knowledge structures, roles, discourse and domains

A concept within a knowledge structure is characterized *extensionally* by the distinction it makes within the domain, and *intensionally* by its properties including its relations to other concepts. Logically, intensional equality between concepts implies extensional equality but not vice versa. Psychologically, one source of inconsistency is that this implication may not hold. In addition, as noted above, since the intensional comparison of concepts involves the terms used in naming them, inconsistencies may arise through terminological differences.

Figure 3 shows the repertory grid methodology in action in a longitudinal study of the knowledge structures of a research team in geography, the relations between those of different team members, and the changes in structures and relationships over time (Gaines and Shaw, 1989; Shaw and Gaines, 1989). The domain is one of mapping techniques, and grids were elicited initially from individual team members. The team was then brought together for a discussion of the mapping techniques, and a common set of techniques was agreed. Each team member then developed a grid for the agreed techniques. These grids were exchanged between members with the ratings removed so that each person rated the mapping techniques using the constructs of the other team members. Figure 3 shows the sorted differences between an original and an exchanged grid, allowing one to see to what extent two team members are using the same terminology in the same way. It is apparent that there are major inconsistencies in terminology between members of a team who had been working closely together for some years. This led to discussion of the basis of the inconsistencies and their roles in conflicts over the 'correct usage' of notions such as a technique 'requiring a model.' It did *not* lead to an agreement over a common use of terminology, but it did focus attention on concepts and terminology where discourse within the team would be problematic through lack of a common usage.

Figure 4 in the left column summarizes the data from Figure 3 and in the right provides additional comparisons derived from the grids prior to their being exchanged. This comparison of the raw grids allows concepts to be paired as corresponding because they appear to be making the same distinction but terming it differently. This again generated discussion leading to significant insights about the knowledge structures involved. For example, the terms *low-level-data—high-level data* and *nominal data—interval or ratio data* corresponding may be interpreted as arising from different *levels of abstraction.*

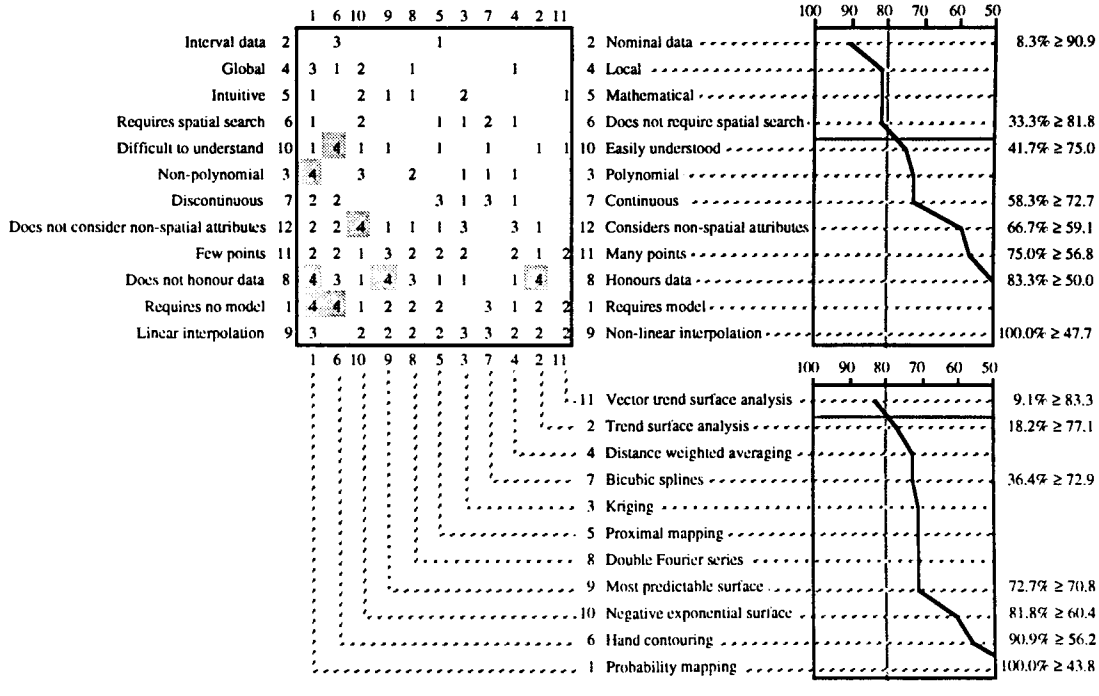

Figure 3 Consensus and conflict between two geographers working together

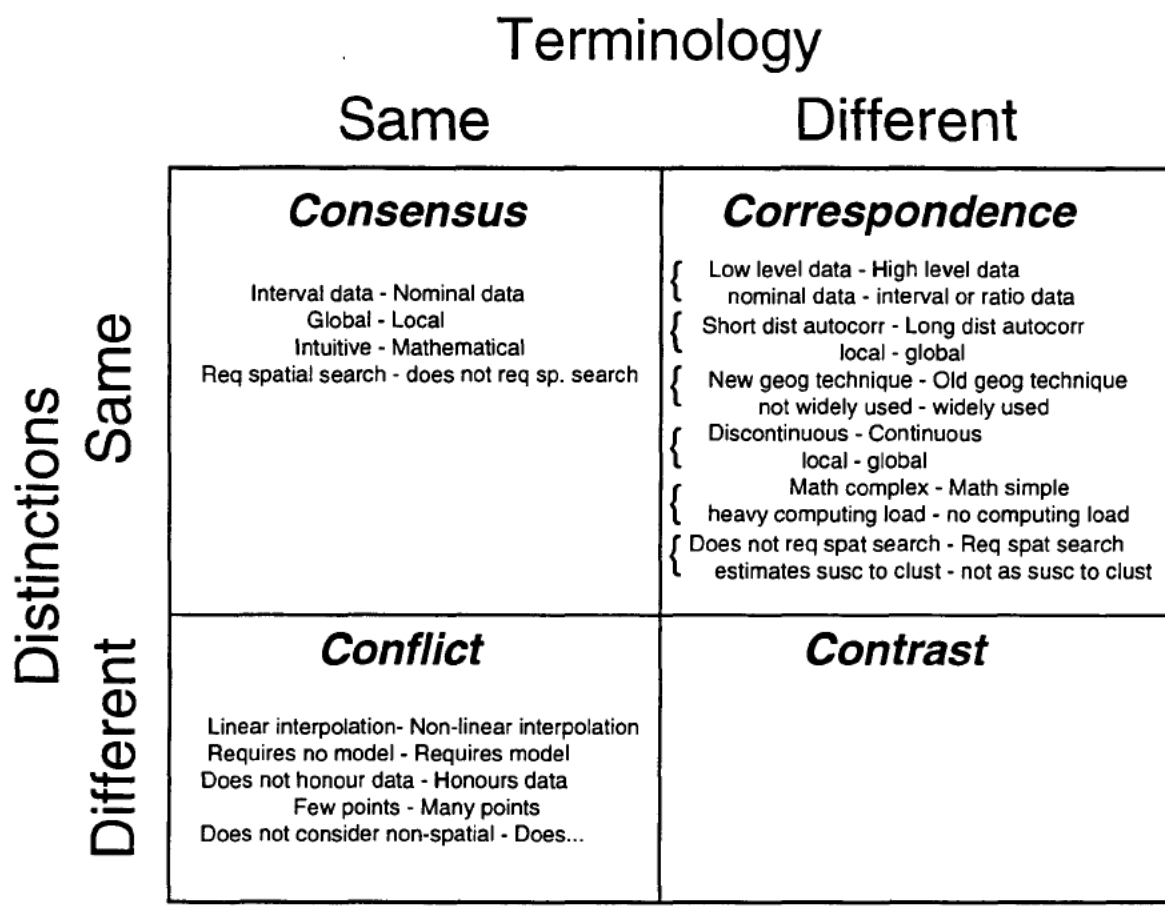

Figure 4 Summary of comparisons between two geographers

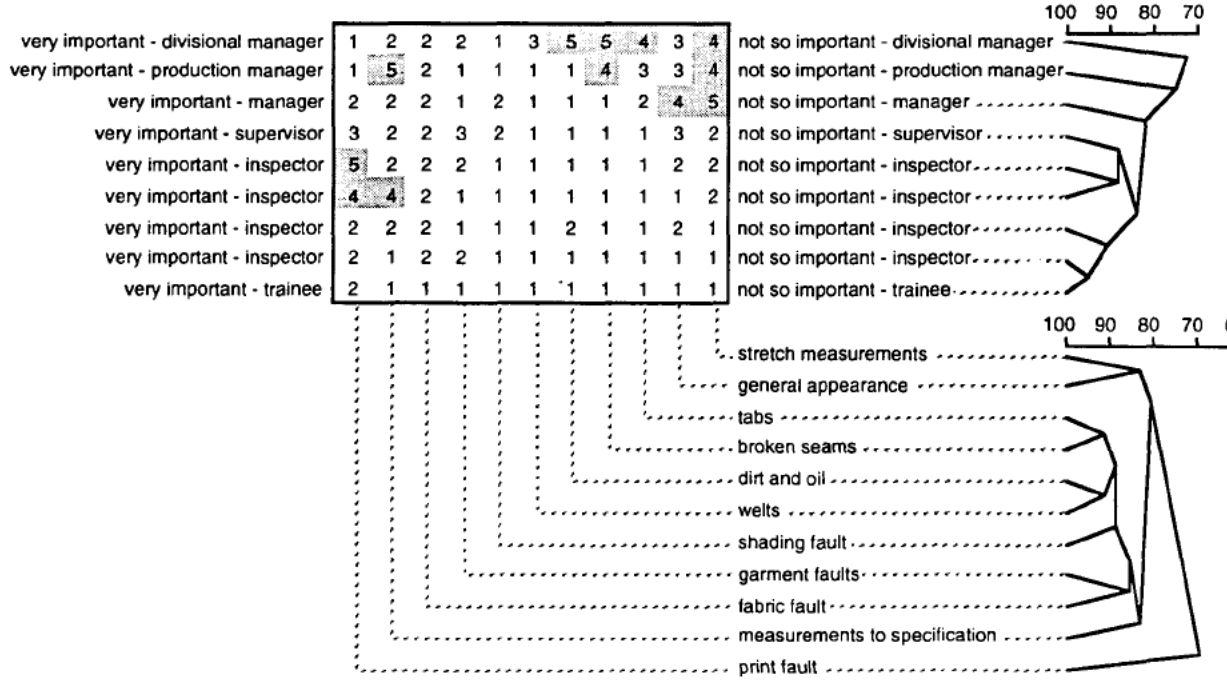

Figure 5 Analysis of conflicts arising in quality control procedures

Figure 5 shows data from another study which used repertory grids to investigate conflicts arising in quality control procedures in a garment factory (Shaw, 1980). In this case employees at different levels of management were asked to construe a set of faults that could occur in the production of garments. As well as their personal constructs, they were each asked to construe the faults on the 'offered construct' of *important—not so important*. The grid shown is a clustered composite of these offered constructs for each individual involved. What was particularly insightful in resolving the conflicts in this case was that the clustering of the knowledge structures faithfully reproduces the management structure of the organization. It was apparent that there was a drift in conceptual structures from one layer of management to the next with the result that the inspectors responsible for quality control were not applying the criteria deemed appropriate by senior management responsible for the commercial relationship with the customer.

ELICITING CONCEPTUAL RELATIONS

Concepts are not isolated but form part of rich semantic networks having many interrelations and associations. The original repertory grid methodology is not suited to mapping this network, and we complement it through the use of concept mapping techniques. Concept maps have long been used as a method to structure argument forms, and as a visual language for expressing relationships between events (Gaines and Shaw, 1993b). Concept maps have been used as tools to support the interviewing process in knowledge acquisition from experts, for example in the Wright-Patterson development of the pilot's associate (McNeese, Zaff, Peio, Snyder, Duncan and McFarren, 1990). In management, Axelrod (1976) proposed cognitive maps as a means of representing the conceptual structures underlying decision making, and these have been used empirically to analyze organizational decision making (Eden, Jones and Sims, 1979) social systems (Banathy, 1991) and the policies of political leaders (Hart, 1977).

In linguistics, Graesser and Clark (1985) have developed an analysis of argument forms in text in terms of structured concept maps with eight node types and four link types, and Woodward (1990) has developed tools to extract such concept maps from text. They have also been used extensively in education, mainly to investigate a student's understanding of some topic such as concepts in science (Novak and Gowin, 1984), and there are many different forms that have been applied in this field (Lambiotte, Dansereau, Cross and Reynolds, 1989). In the history of science, the dynamics of concept maps have been used to represent the processes of conceptual change in scientific revolutions (Nersessian, 1989; Thadgard, 1992). In the philosophy of science, Toulmin (1958) developed a theory of scientific argument based on typed concept maps that is regarded as one of the major models of the rhetoric of western thought (Golden, Berquist and Coleman, 1976).

KMap is a generalized visual language tool that provides a user interface and data structures for creating, editing, analyzing and exporting typed graphs with directed and undirected links (Gaines and Shaw, 1993b). The user interface allows KMap to be tailored to particular requirements by specifying the node types required, and associating with visual interface characteristics such as shape, color and text attributes. KMap recognizes a variety of user interface items, such as menus and buttons, that need not be specified in advance, and this enables its interface to be tailored by specifying different interface resources rather than modifying code. The specified types and interface then allow graphs to be generated using these node types together with lines and arrows as links. Links may be labeled using specified link label node types. KMap supports all the interactive graphical capabilities for editing, printing and so on. It supports an inter-application communication protocol enabling other programs to make use of the graphs, and to interact with the users through the graphs. Hence it may be used as a front end to many other systems such as conceptual graph and KL-ONE deductive systems, qualitative simulation systems, and Petrinet and category-theoretic proof systems. KMap may also be used more informally to specify concept mapping environments, and to develop concept maps within them.

Case Map is an interviewing tool designed to support the sequential development of structured concept maps (Woodward and Shaw, 1994). It is comprised of two main components. The first component takes a list of questions provided by the facilitator and inserts them in a display sequence shown to the group participants. This component stores the information in list form to be used by the mapping component and can also be used by other automated knowledge engineering tools. The second component, KMap, graphs the resulting questions and their responses in an interactive graphing environment. The two components are fully integrated so that any changes in one component is automatically displayed in the other.

One interviewing technique of particular interest in the context of this workshop is one based on another methodology derived from personal construct psychology, that of *laddering* (Hinkle, 1965; Gaines and Shaw, 1993a). Laddering tools take a concept such as a specified goal and ask two types of question: laddering up, *why* should that goal be satisfied; laddering down, *how* can that goal be satisfied? In interactive elicitation the participant is taken up and down the conceptual structure by sequences of such how and why questions.

In a group situation we first elicit the consensual core constructs of the group relating to its primary reason for existence, use Case Map to ladder this core for each participant, and then use KMap to display to the group the semantic network of encircling individual construct systems about the group core. This generally exposes major conflicts between individual participant's perceptions of the rationale for the group, and between their differing approaches to achievement of the consensual goals. In a properly facilitated environment this exposure provides a major impetus to group creativity and goal achievement because the strength through diversity of the group is apparent, and conflict resolution becomes seen as a route to goal achievement rather than as an unwelcome impediment.

Examples of concept maps derived in a variety of ways for a major international research project are given in a paper in the main AAAI94 proceedings (Gaines and Shaw, 1994). It is noted in that paper that the sources of many of the conflicts that arose in the operation of that project are immediately apparent in the concept maps. For example, some sub-projects are represented in great detail whereas others are hardly represented at all, and, in practice, the under-represented projects were sources of conflict because there was no consensus on their objectives and relation to the project as a whole. However, it should also be noted that the effort to resolve these conflicts resulted in achievements that might not have occurred otherwise. Conflict in itself is not to be avoided. It is a by-product of inconsistencies in knowledge structures impeding group coordination, and is part of the process of dealing with such inconsistencies. Making the inconsistencies overt generally helps the resolution of the conflict, but not necessarily through a consensus on the use of concepts and terminology. Individuals often 'agree to disagree', but their overt recognition that they are doing this helps to improve coordination in group discourse and cooperative action.

CONCLUSIONS

The theoretical foundations for individual and collective dynamics have been developed in terms of relations between knowledge structures. It has been noted that neither individuals nor collectives need to be consistent in their knowledge structures to achieve effective performance, and that the notion of conflict arises in modeling failures in coordination attributed to such inconsistency. Methodologies for eliciting and modeling knowledge structures from individuals and groups have been described, and examples have been given of the methodologies applied through computer-based systems to make overt the nature and sources of conflict.

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